Top Quark Physics at DØ

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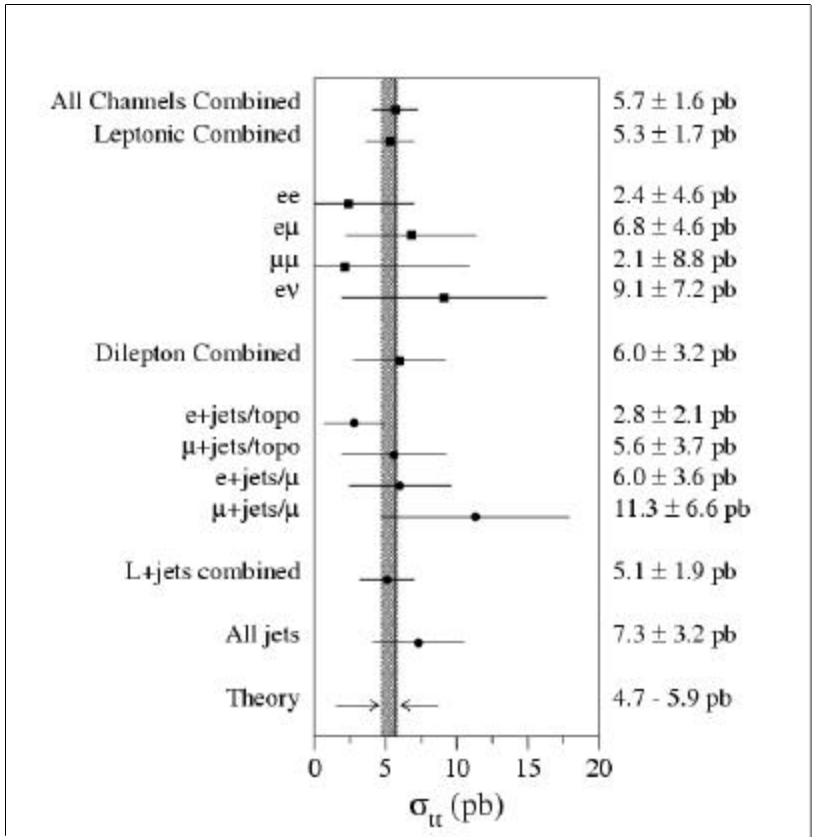
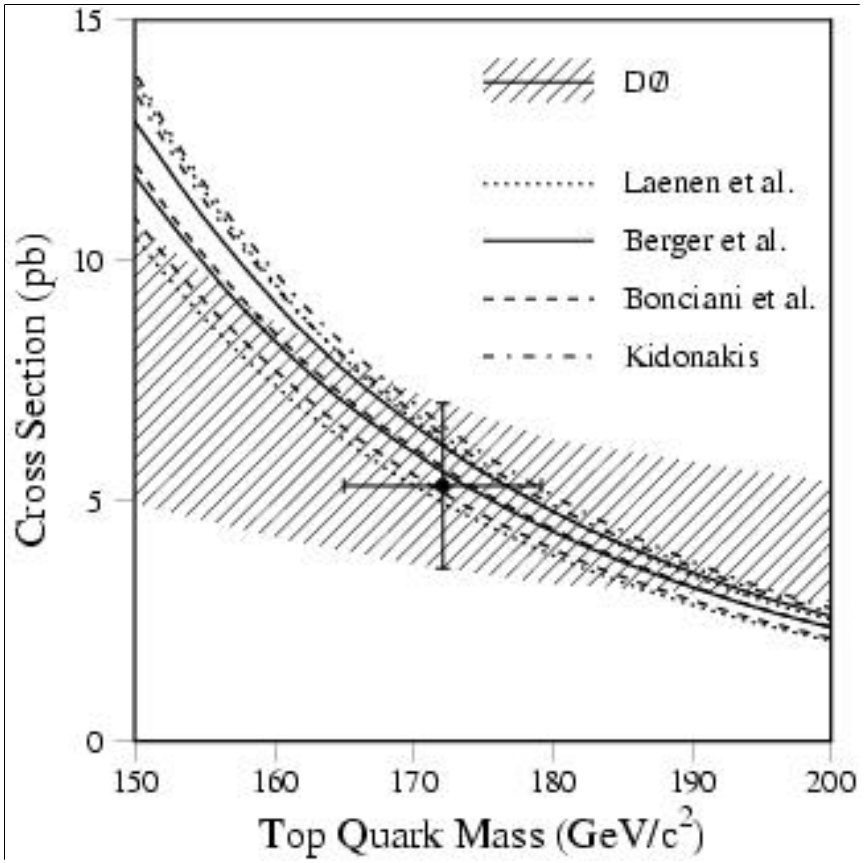
Top Talk

- **Why is this compelling physics?**
  - **Top is coupled**
    - Through EW radiative corrections, the W mass depends on the top mass and Higgs mass
  - **Top is heavy**
    - Top couples to the Higgs with coupling strength ? (1)
  - **Top is free**
    - Top decay time < hadronization time
  - **Top is unexplored**
    - We measured the t-tbar production cross section and top mass but not much else
  - **Top is a window**
    - Top decays to MSSM Higgs?
    - Topcolor-assisted technicolor?

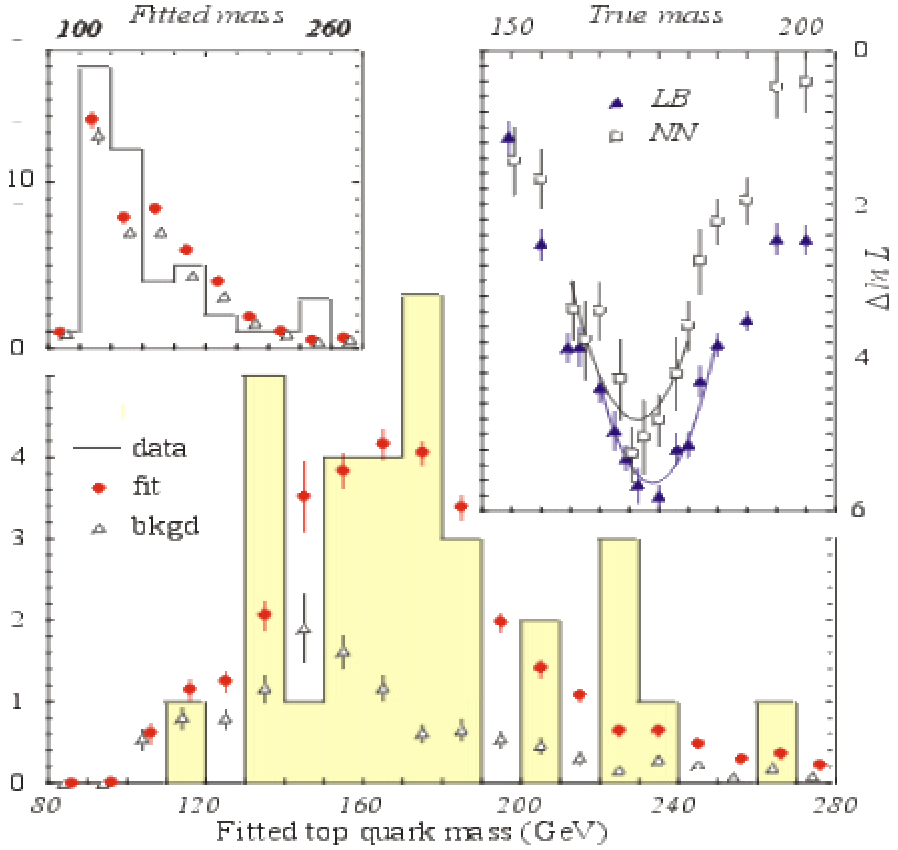
Run I Top Cross Section

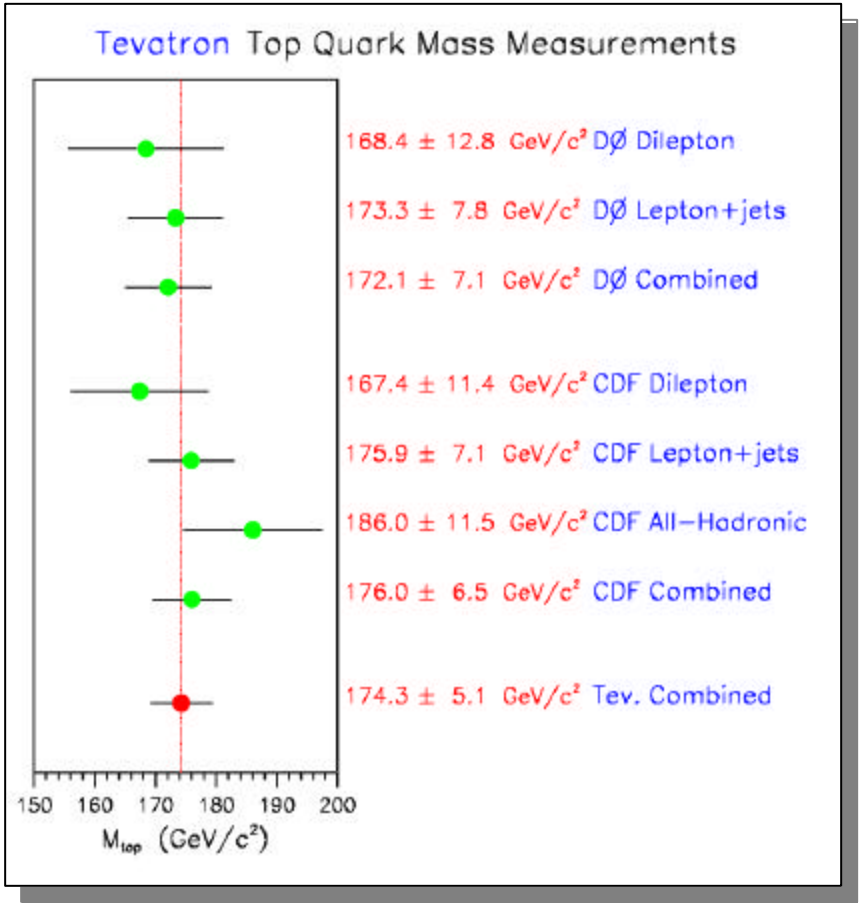




- **Updated leptonic cross sections**
- **Comparison with theory**

Run I Top Mass

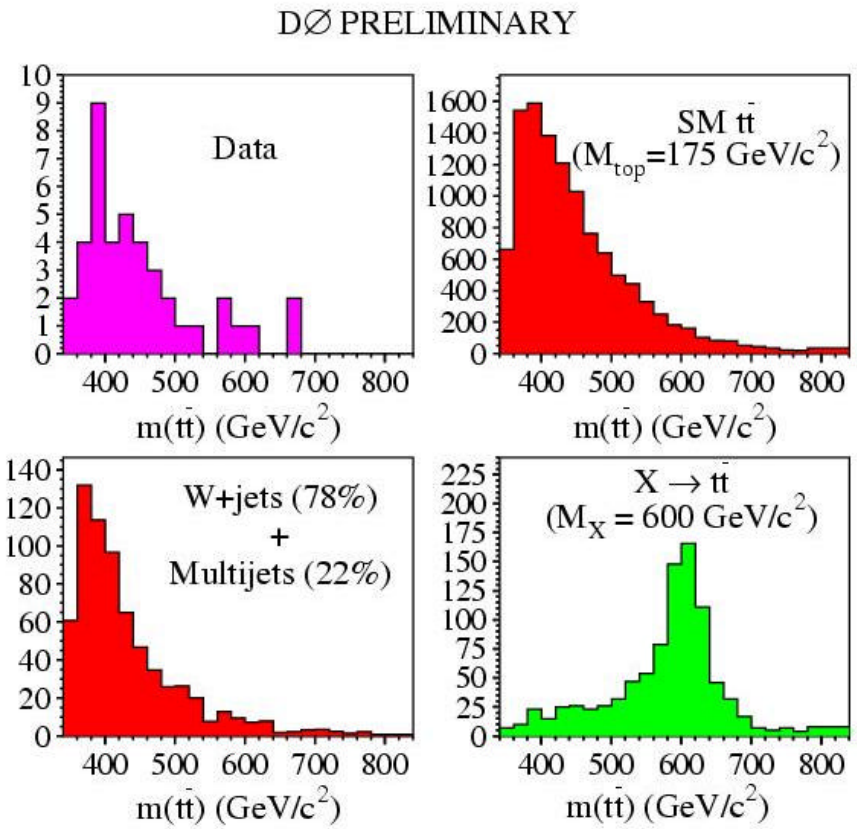




- **Fitted top quark mass using leptons plus jets**
- **m_t = 174.3±5.1 GeV/c^2**

Search for t-tbar Resonances (Run I)

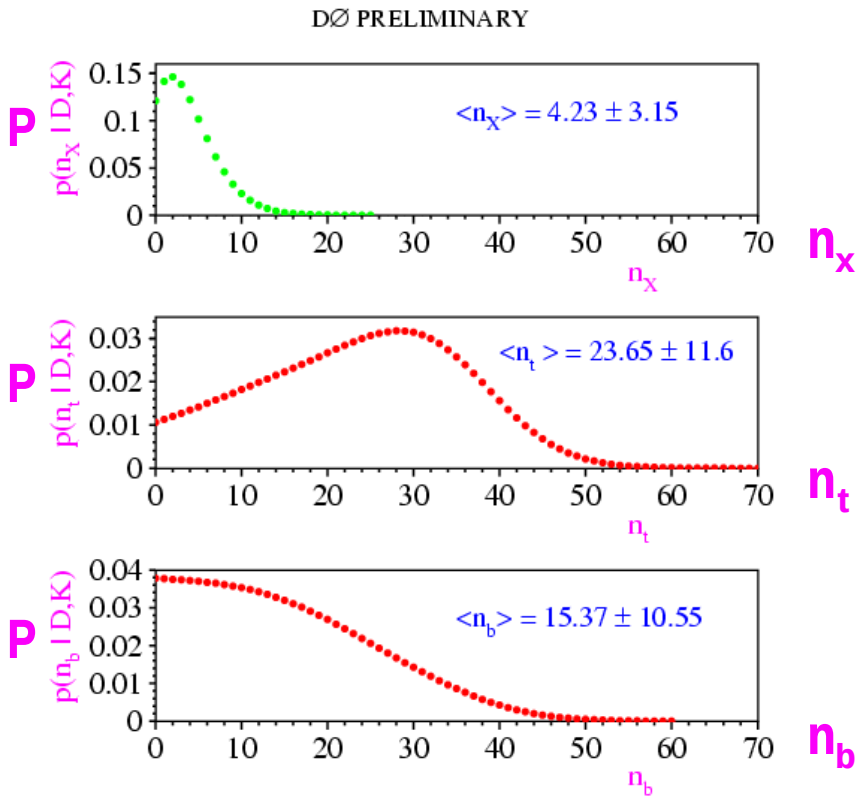
- Motivation is to investigate models that dynamically break EW symmetry
- An example is topcolor-assisted technicolor which implies the existence of a heavy Z' that strongly couples to t-tbar pairs
- Search for narrow resonances X -> t-tbar (model independent) in leptons plus jets sample



- Perform 3C kinematic fit using m_W and m_t as constraints

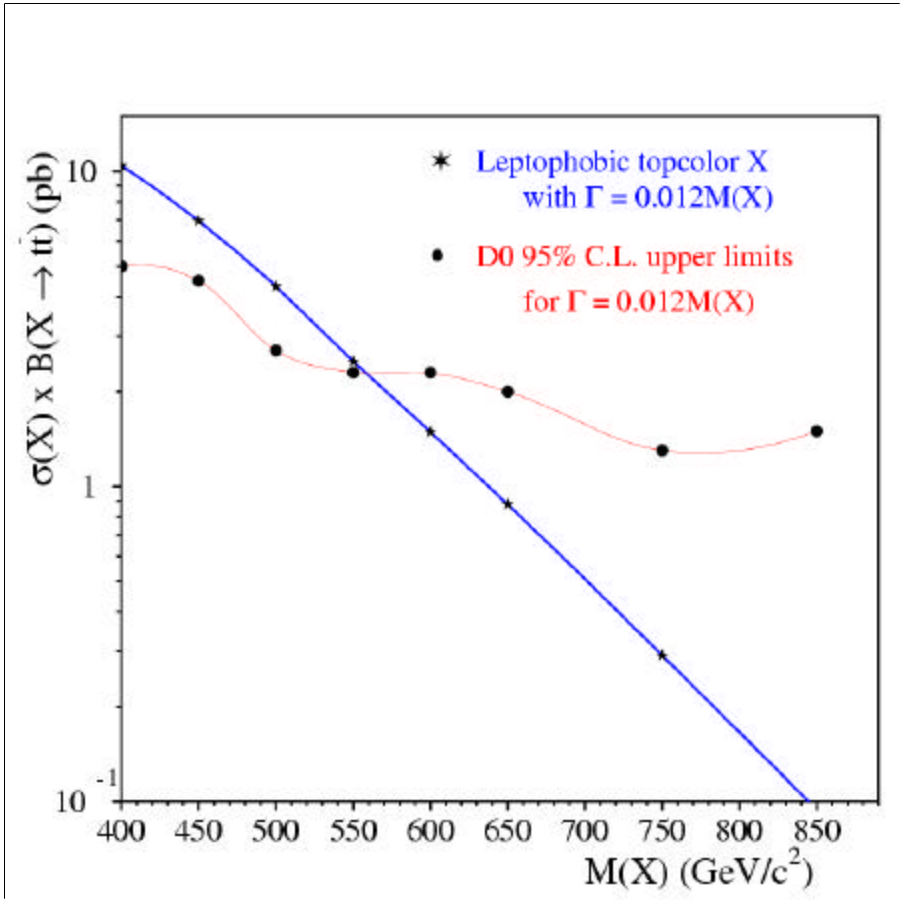
Search for t-tbar Resonances (Run I)

- Use Bayesian statistics to derive posterior probability distributions P(n|D,K) by fitting m_{t-tbar} from data to weighted sum of three sources
- No statistically significant excess is observed
- Writing $n_X = A \cdot L_{int} \cdot s_X \cdot B$ (where A is the acceptance) we can define $s_X B$ at 95% CL



- For m_X = 600 GeV/c^2

Search for t-tbar Resonances (Run I)



- We exclude a narrow, leptophobic X boson with $m_X < 560$ GeV/c^2

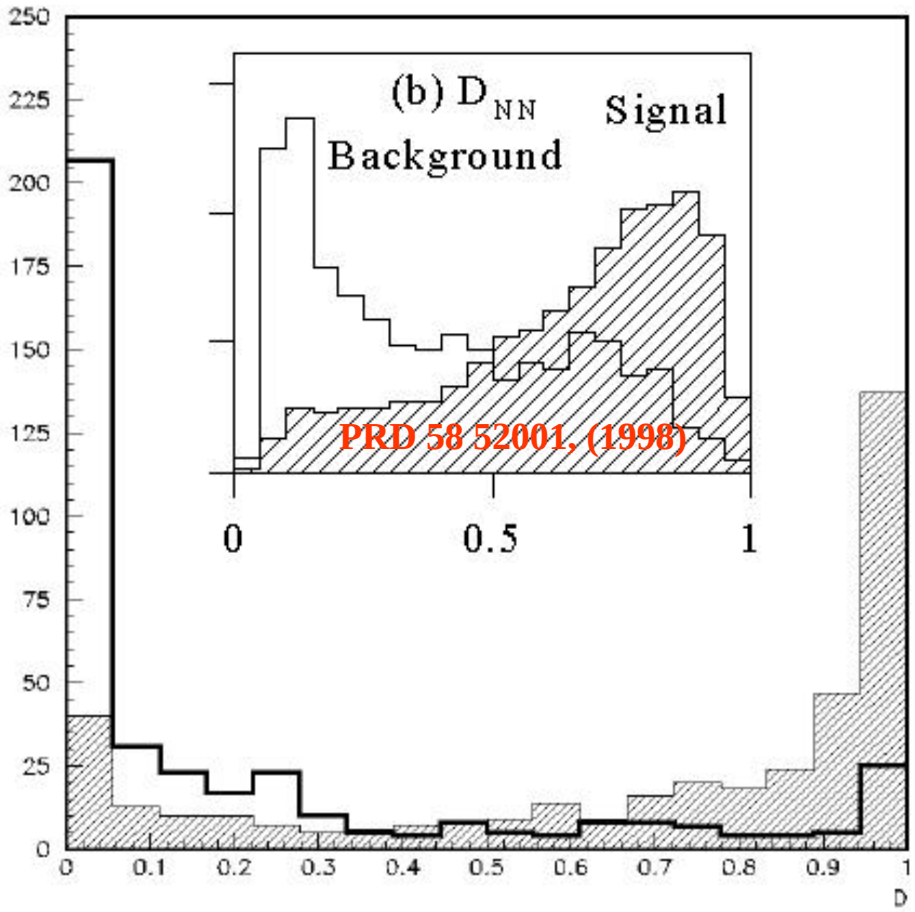
- Systematic uncertainties are accounted for by convoluting the posterior probability with a Gaussian prior for $A \cdot L_{int}$
- Systematic sources
  - ISR/FSR (16%)
  - PDF (15%)
  - Luminosity (4.3%)
  - Jet energy scale (5.2%)
  - Trigger/ID efficiencies (3.5/3.8 %)

New Analysis Methods for Top

- **Similar in spirit to Dalitz et al.**
  - For each event, a probability distribution is calculated using the full kinematic information in the event except MET
  - The probability is calculated using the matrix element for production and decay

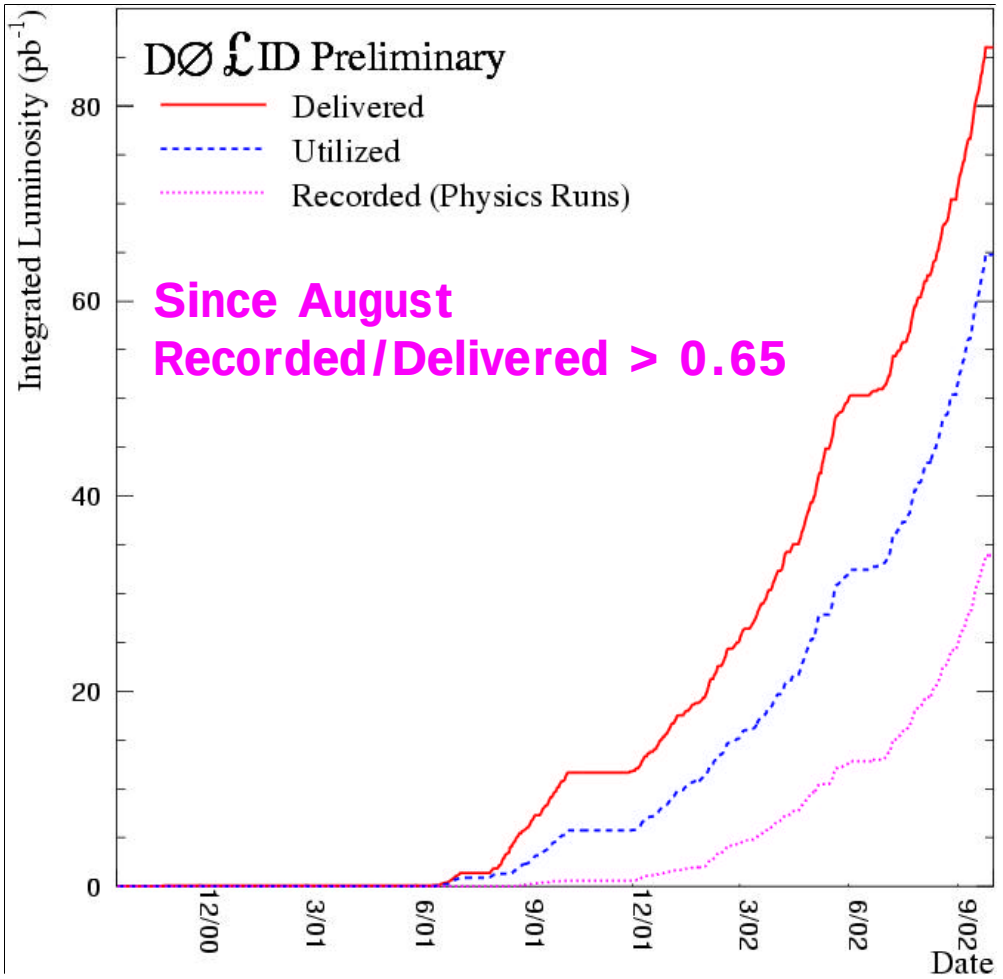
$$P_{\bar{t}t} = \int dr_1 dm_1^2 dM_1^2 dm_2^2 dM_2^2 \sum_{comb\,n} |M|^2 \frac{f(q_1) f(q_2)}{|q_{1|}||q_2|} f_6 W(x,y)$$

  - Detector acceptance, detector resolution, and background is accounted for as well
  - Leads to much improved S/B and reduced statistical uncertainty in m_t
- **See talk by Juan Estrada on Friday**



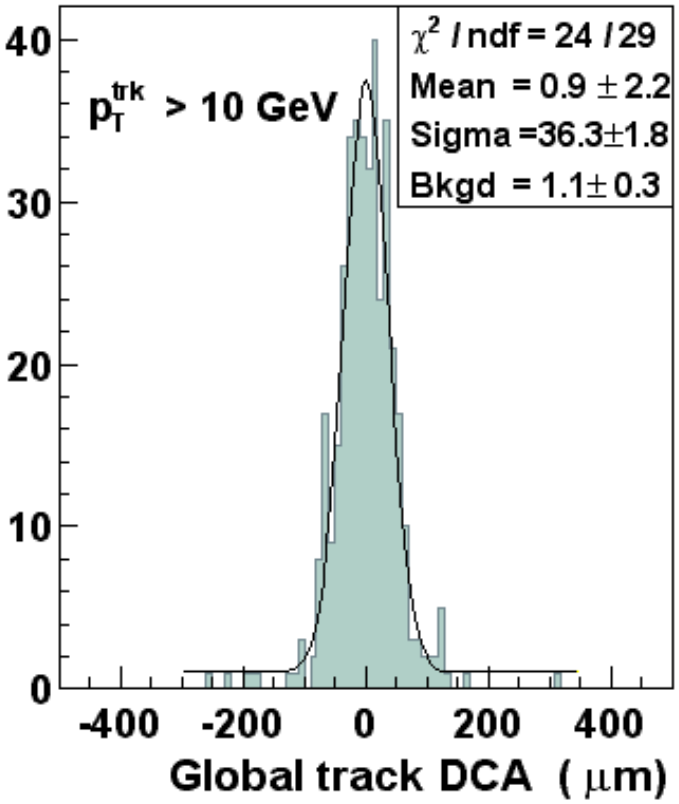
DØ Status

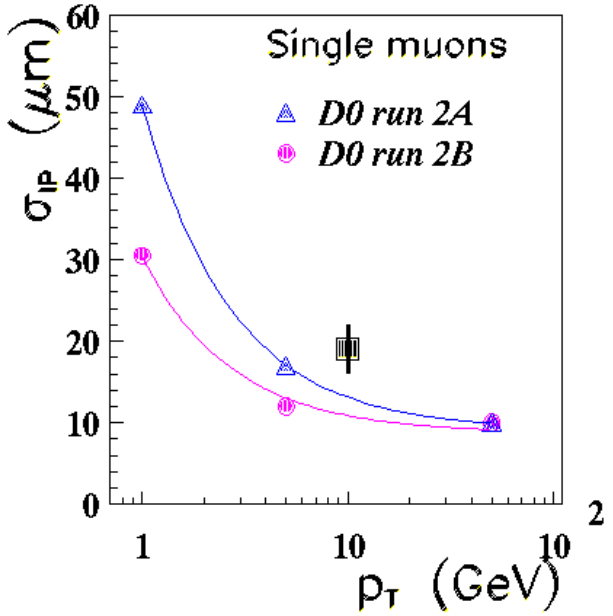
- All detector systems fully operational
- But many L1/L2/L3 triggers are continuing commissioning
  - L1/L2/L3 rate = 400/200/40 Hz
- Goal is analysis of 50 pb^{-1} for spring conferences



Impact Parameter (IP) Resolution

- With initial silicon and no central fiber tracker alignment, IP resolution near beam resolution
- Assuming a beam spot size of 30μm
- Current performance is approaching design spec





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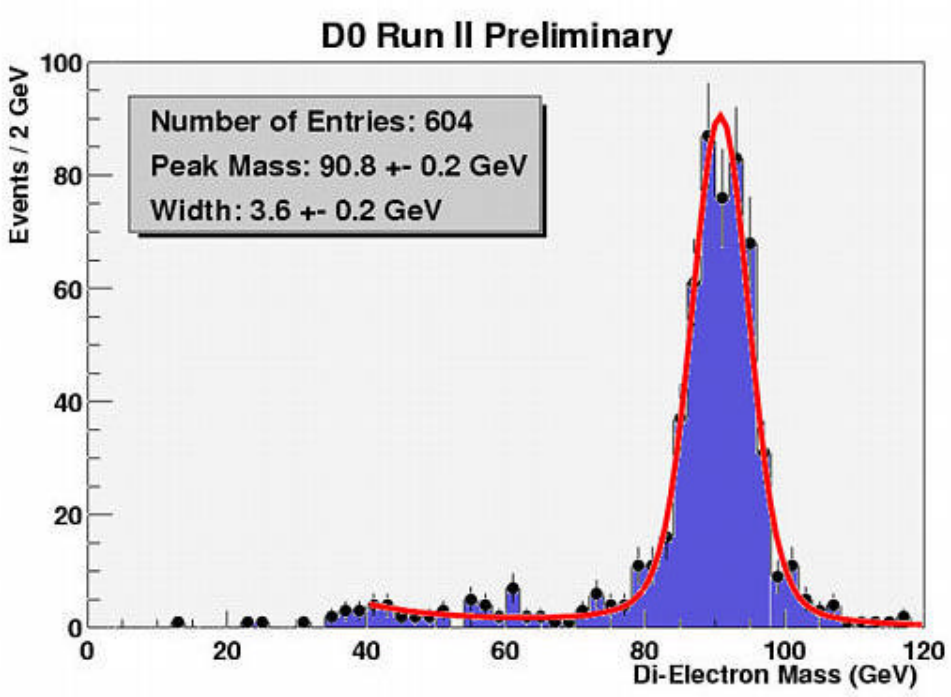
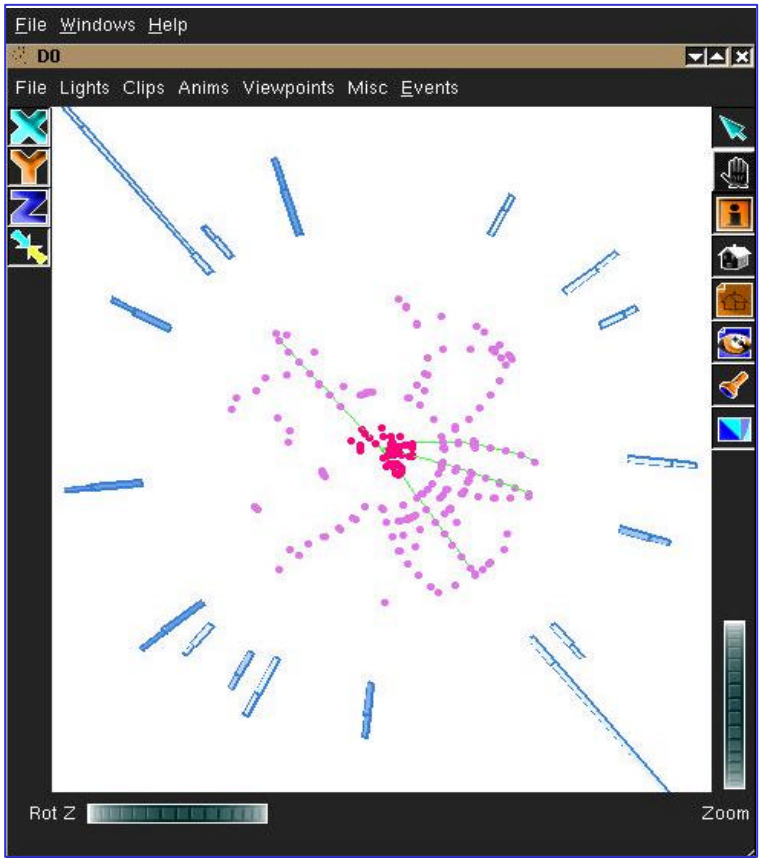
Z -> e^+e^- Candidates





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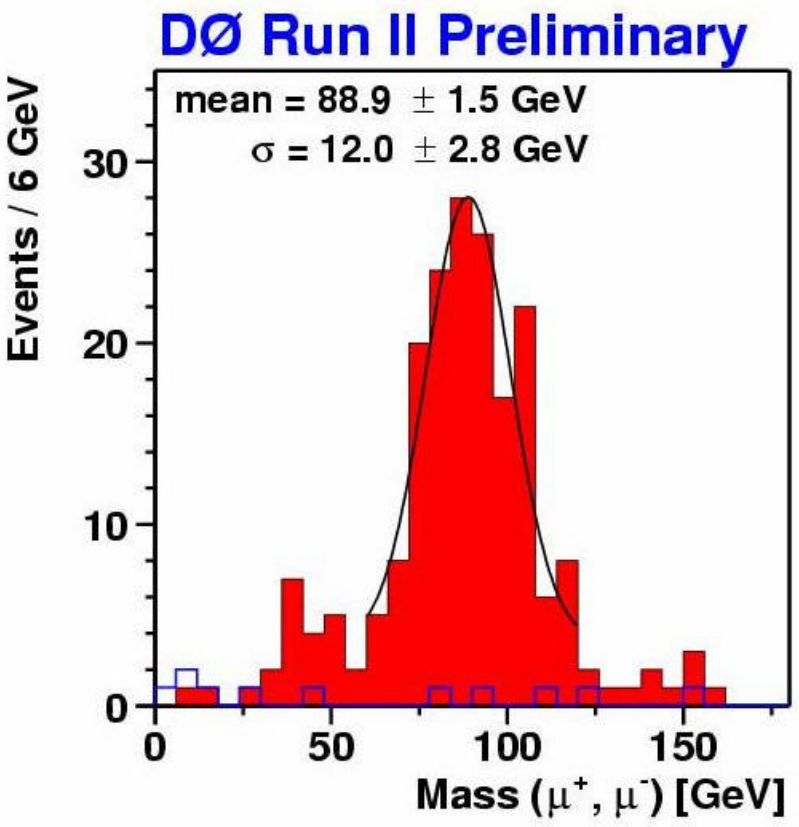
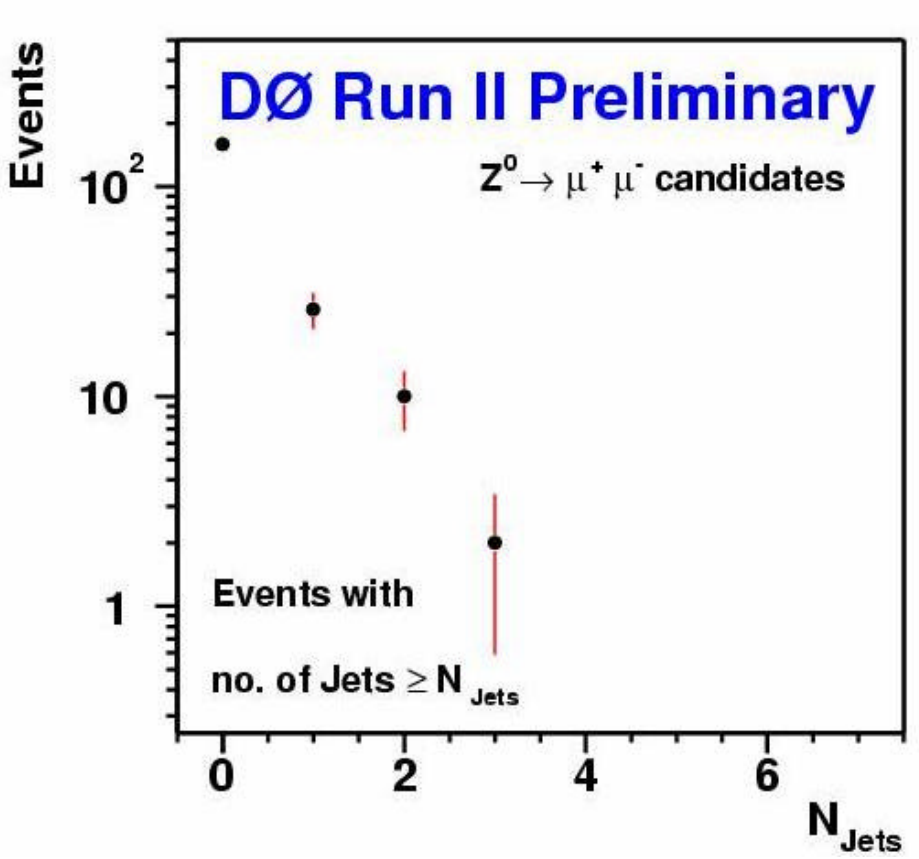
Z -> $\mu^+\mu^-$ Candidates





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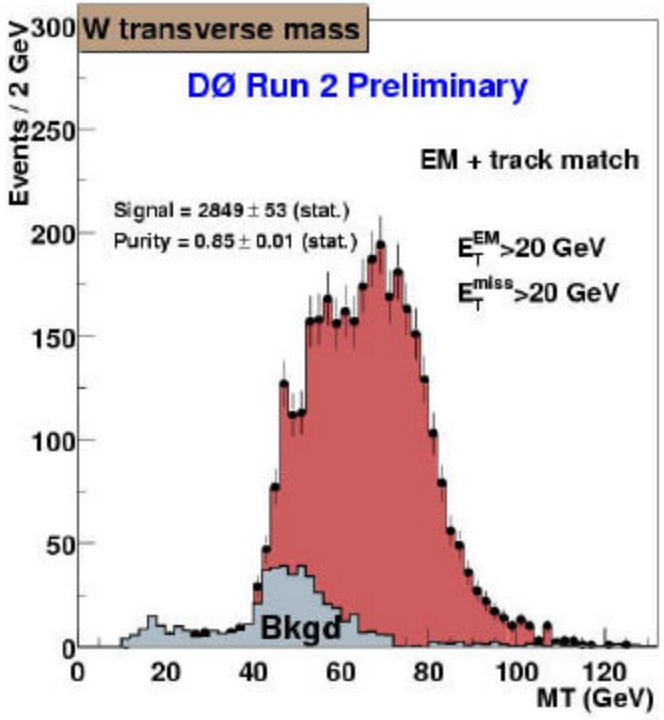
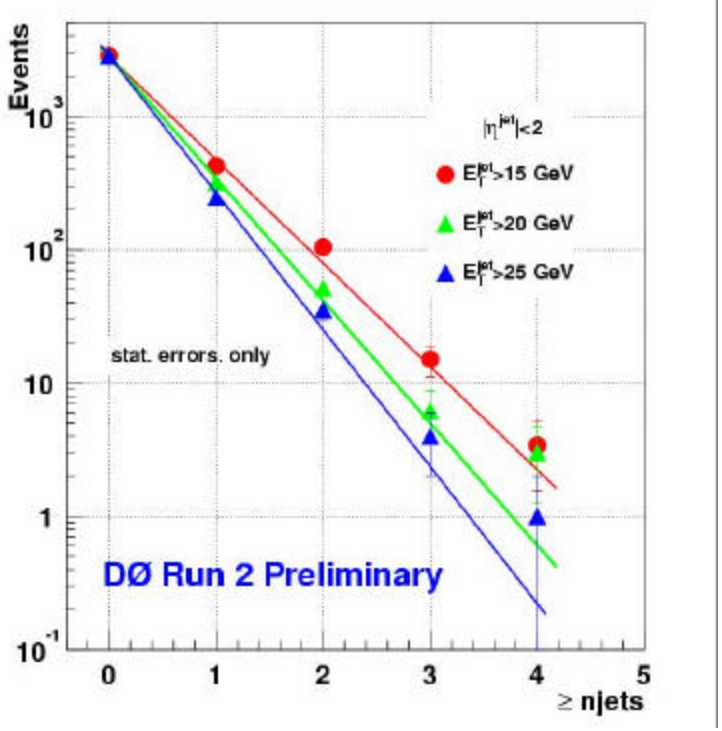
W -> en+jets Candidates





- QCD background derived from low E_T^{miss} data
- ?Ldt = 7 pb^{-1}

- Background subtracted
- Signal efficiency from Z's
- Obeys Berends scaling

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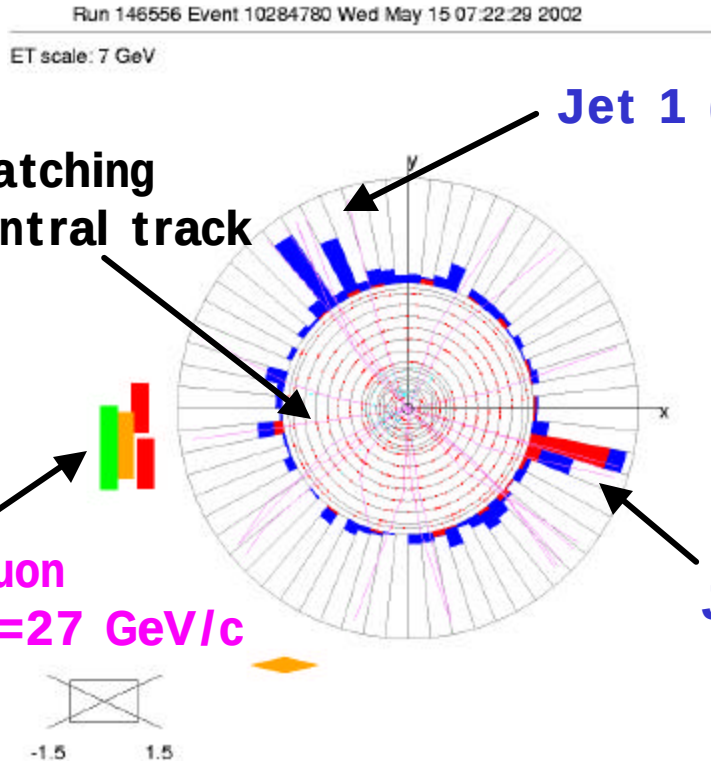
W -> μn+jets Candidate

Missing E_T (23 GeV)

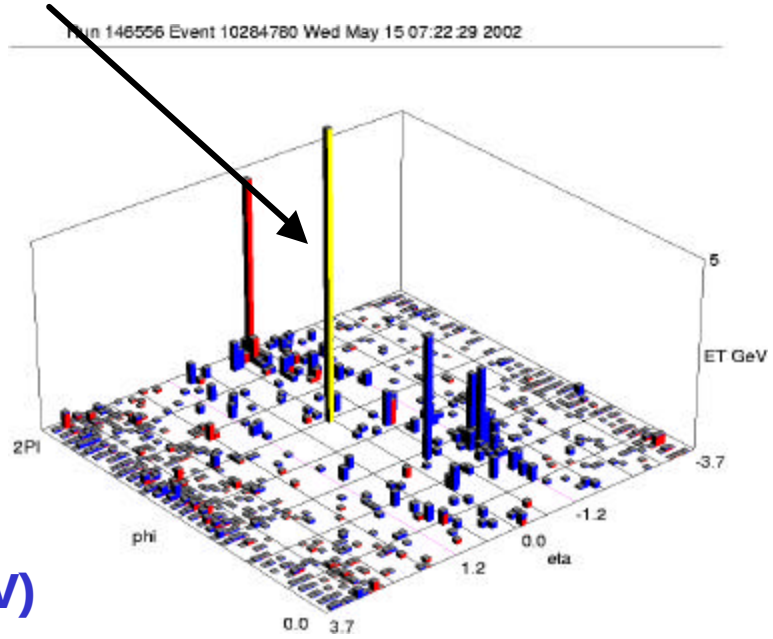


Jet 1 (E=38 GeV)

Matching central track

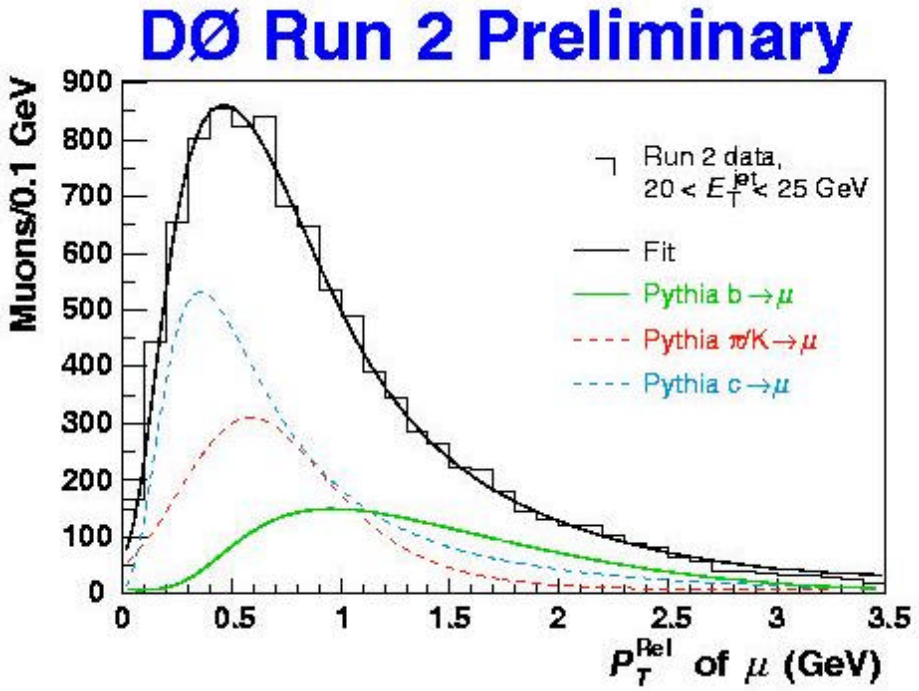
Muon P_T=27 GeV/c

Jet 2 (E=15 GeV)

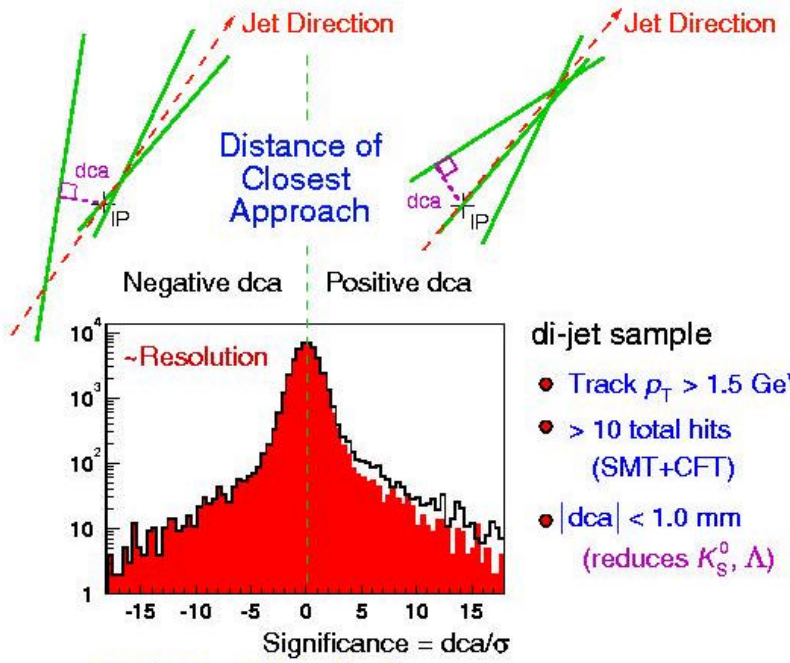


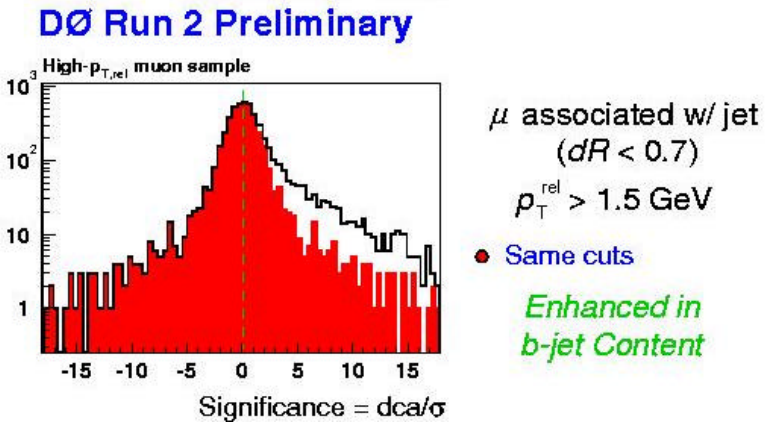
b-tagging

- **Tagging with soft leptons**
  - **Dijet events with an associated muon tag**
  - **Work on electron tagging in progress**



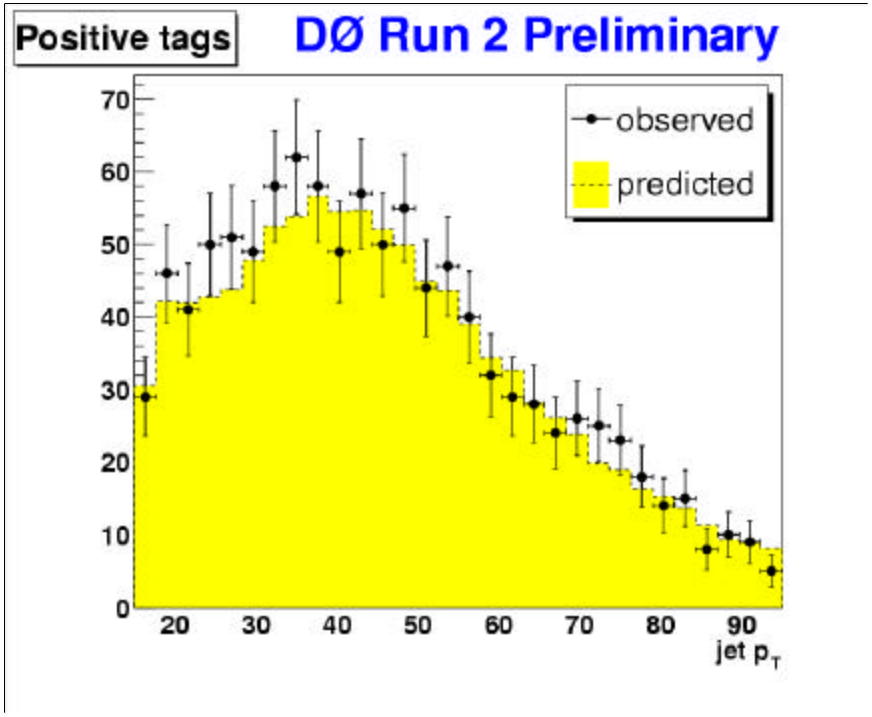
- **Tagging via Impact Parameter**

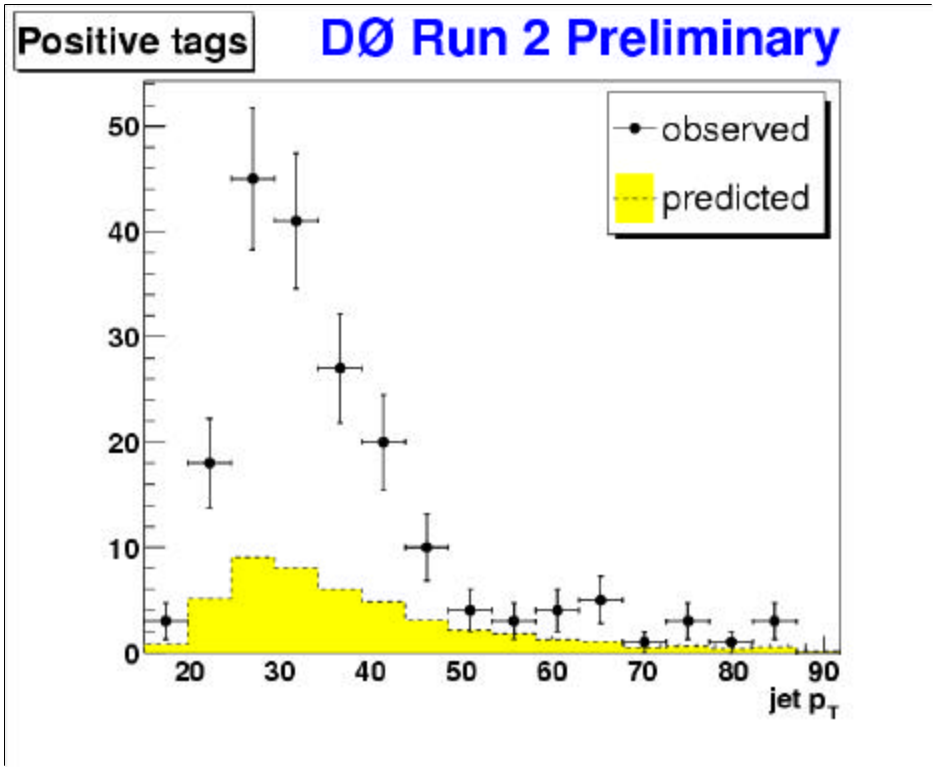




b-tagging

- Secondary vertex tag in jets
- Secondary vertex tag in muons plus jets



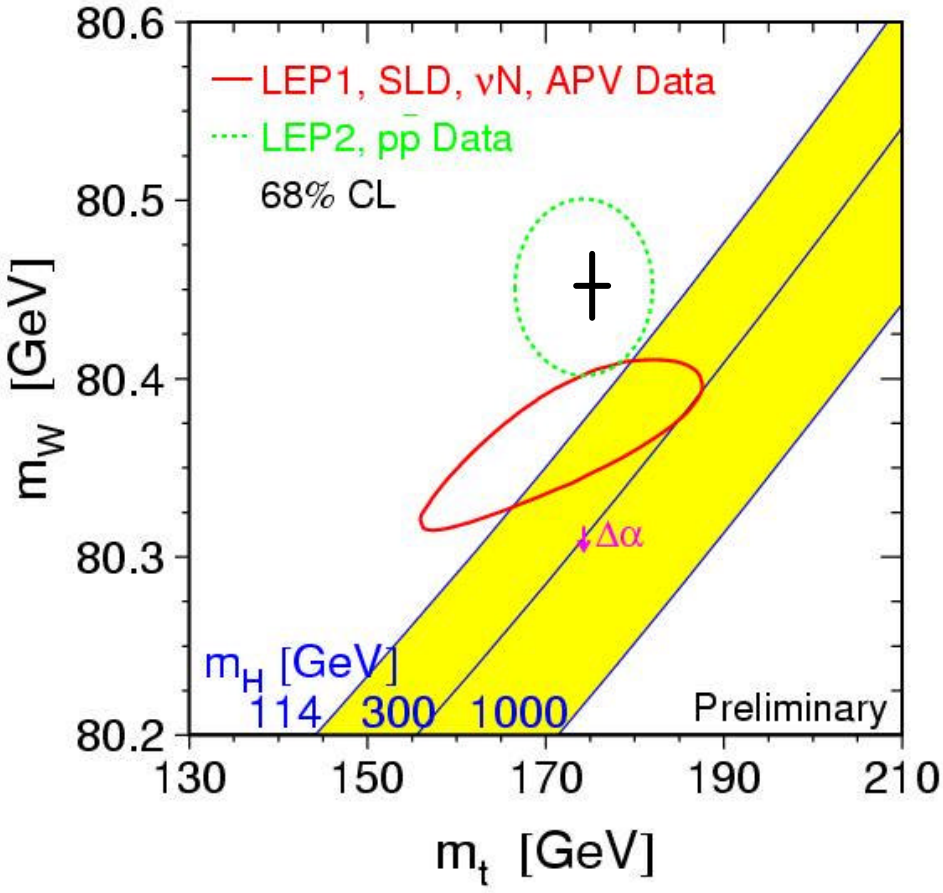


Run IIa Top Mass

- Improved particle ID using improved detector
  - Particle ID efficiency errors should decrease with higher statistics
- Reduced statistical error
  - Increases in Tevatron energy and integrated luminosity should provide ~40x increase in data for top and background studies
- Reduced systematic errors
  - Increased statistics of ? + jets and Z+jets, Z -> b-bbar (via silicon track trigger), and hadronic W in top decays should decrease jet energy scale error < 1 GeV
  - Improved Monte Carlo modeling of signal and (W+jets) background and constraints to data should decrease these errors
- Improved analysis techniques
  - Matrix element method

Run IIa Top Mass

- **Indirect constraint of the Higgs mass**
  - **Goals of 2 GeV and 30 MeV errors in RunIIa measurements of m_t and m_W**
  - **Goals of 1 GeV and 15-20 MeV errors in Run IIb measurements of m_t and m_W**



Other Run IIa Top Physics

- t-tbar and single top cross sections
  - Former is sensitive to anomalous couplings
  - Latter is a direct measurement of G(t->Wb) and $|V_{tb}|$
  - In Run I, DØ search for single top resulted in limits of s_s < 17 pb and s_t < 22 pb (compared to expected SM values of 0.73 and 1.73 pb)
- Decay properties
  - W helicities, kinematic distributions, rare and non-SM decays (t -> ?q, Zq, t-> H^+b, …)
- Production properties
  - Resonance search in $m_{t\text{-}tbar}$, spin correlations, …

Run IIb and Top

- Tevatron plan is 2 fb^{-1} by 2004 (Run IIa) and 15 fb^{-1} by 2008 (Run IIb)
  - Increase number and efficiency of p-bars
- DØ will upgrade the SMT and hardware trigger systems between Run IIa and IIb
  - Six-layer silicon with six axial and four stereo layers including an L0 at r=18mm
  - New L1 calorimeter, L1 central track trigger, and L2 silicon track trigger hardware
- Primary physics objective is the Higgs hunt
  - p-pbar -> t-tbar H?
  - SM properties and non-SM physics of top

Run IIa and Run IIb Top Reach

	Run1 prec.	2fb^{-1}	15fb^{-1}
M_t (combined)	2.9%	1.5%	0.8%
σ(ttbar)	25%	10%	5%
W helicity, F_0 W helicity, F_+	0.4 0.15	0.09 0.03	0.04 0.01
R=BR(t->Wb)/BR(t->Wq) $\|V_{tb}\|$, lower limit at 90% C.L.	30% >0.05	4.5% >0.25	0.8% >0.50
σ(single top) Γ(t->Wb) $\|V_{tb}\|$	- - -	20% 25% 12%	8% 10% 5%
BR(t->gq) at 95%CL BR(t->Zq) at 95%CL	0.03 0.30	2 x 10^{-3} 0.02	2 x 10^{-4} 2 x 10^{-3}

Conclusions

- Both the Tevatron accelerator and DØ experiment have moved into stable operation
  - Additional (adiabatic) improvements are expected in both
- DØ has made a good start towards re-discovering top
  - Serious searches for top in all channels have begun
  - Results from 50 pb^{-1} are expected by spring
- Run IIa will provide a rich spectrum of top physics (and hopefully some new discoveries)